AFGL-TR-76-0172

PLATE TECTONICS AND THE DISCRIMINATION OF UNDERGROUND EXPLOSIONS FROM EARTHQUAKES

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May 1976

Semi-Annual Report No. 1

Approved for public release; distribution unlimited

Sponsored by:

Defense Advanced Research Projects Agency
ARPA Order No. 1975

Monitored by:

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

ARPA Order No. 1795

Program Code No. 1F10

Name of Contractor: Columbia University

Effective Date of Contract: 1 October 1975

Contract Expiration Date: 30 September 1976

Contract No. F 19628-76-C-0075

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 19 AFGL-TR-76-0172	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) PLATE TECTONICS AND THE DISCRIMINATION OF UNDERGROUND EXPLOSIONS FROM EARTHQUAKES.	5. TYPE OF REPORT & PERIOD COVERED Semi-Annual Report No. 1, 1 October 1975-30 March 1976,
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Andrew J. Murphy	8. CONTRACT OR GRANT NUMBER(s) F 19628-76-C-0075, ARPA Order-1975
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 179500 AF-1975
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Geophysics Laboratory Hanscom AFB, Massachusetts 01731 Contract Monitor: Ker C. Thomson, LW	12. REPORT DATE 19 August 1976
	13. NUMBER OF PAGES 7 9p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

A - Approved for Public Release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This research was supported by the Defense Advanced Research Projects Agency ARPA Order No. 1975

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

M_s/m_b variation	great shallow earthquakes
depth	tsunamis
focal mechanism	surface waves
size and duration of source	Tibetan Plateau

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the six month period covered by this report, research was carried out in the following three areas of interest to this contract.

(1) A study of the velocity structure under the Tibetan Plateau using at least ten Tibetan earthquakes recorded by nearby WWSSN stations,

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(2) A study of causes of variations in Ms-m_b (Msubb) relation for a Central Asian earthquake sequence. ~~The purpose of the study is to~~ determine what factors other than source depth and focal mechanism control the surface wave magnitude for small events; and

(3) ~~A~~ study of the distribution of great shallow earthquakes.

Line - Item 001a

Causes of M_s:m_b Variations within a Central-Asian Earthquake Sequence

A foreshock-mainshock-aftershock sequence in the Kirgiz-Sinkiang border region is studied to determine what factors other than source depth and focal mechanism control the surface-wave magnitude of small events. Using a comparative event technique, the mechanism and depth of the events is deduced from azimuthal radiation patterns of Love and Rayleigh waves. All the events appear to be 5-10 km deep, with predominantly thrust motion on a fault plane dipping about 30° from horizontal. Differences in mechanism and depth do not adequately explain the dramatic variation in surface wave amplitude within the series of aftershocks (see figure 1). For example, one aftershock with m_b 5.2 generated surface waves roughly 12 times larger than another aftershock with m_b 5.0.

The earthquakes can be divided into two categories: those which excite long-period signals efficiently, such as the mainshock and several aftershocks; and those which do not, such as the foreshock and the majority of the aftershocks. The primary difference between the two groups may be the finite size or duration of the source. When observed teleseismically, the second group typically generates a very simple, short-period P-wave concentrated within the first 1 to 2 s (upper trace, figure 2), suggesting nearly a point source. However, earthquakes within the first group generate a much more complex short-period P-wave, with substantial energy spread out over the first 10 to 15 s, as shown in the lower trace of figure 2 (duration of time marks is 2 s). The maximum amplitude of the short-period signal is not a very complete description of its character. A better description would include both amplitude and duration, as when the area of the envelope of the short-period record is measured. A comparison of these two measures of earthquake size is given in figures 3 and 4, which show log of maximum amplitude (i.e. m_b) and area of short-period envelope, respectively, when plotted versus M_s. Using the area of the envelope in place of m_b will remove much of the scatter in M_s-m_b relations, without greatly increasing the effort involved in making the measurements. These observations suggest that finiteness of the source can play an important role in controlling M_s:m_b, even for earthquakes with body wave magnitude 4.8 or smaller.

Distribution of Great Shallow Earthquakes

Based on a world-wide survey of great earthquakes, Kelleher and McCann (1976) found that the distribution of large shallow earthquakes along subduction boundaries does not agree with the distribution pattern that might be predicted from a simple model of plate tectonics. That is, along extensive sections of some island arcs large shocks occurred infrequently or not at all during recorded history. Most of these zones of long-term quiesence are nearly coterminous with segments of the margin where zones of seamounts, aseismic ridges or other bathymetric highs of the underthrust slab appear to be interacting with the subduction process. This spatial correlation suggests that at least some of the long-term absences of great shocks may result from a tectonic origin and not from temporary intervals of strain accumulation. Thus, major departures from classic subduction activity may develop where significant bathymetric features interact with a convergent margin.

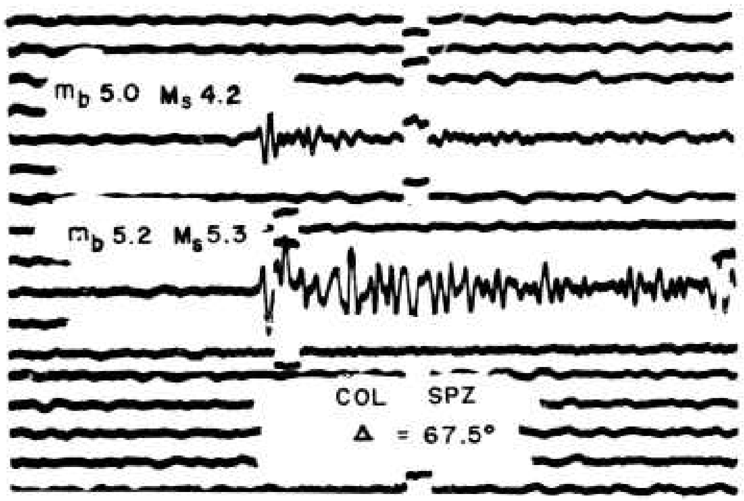

Fig. 1.

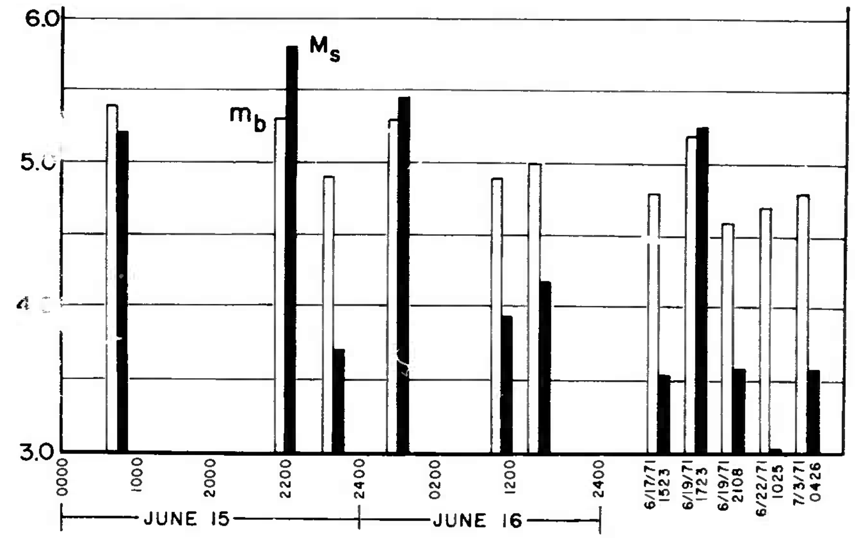

Fig. 2.

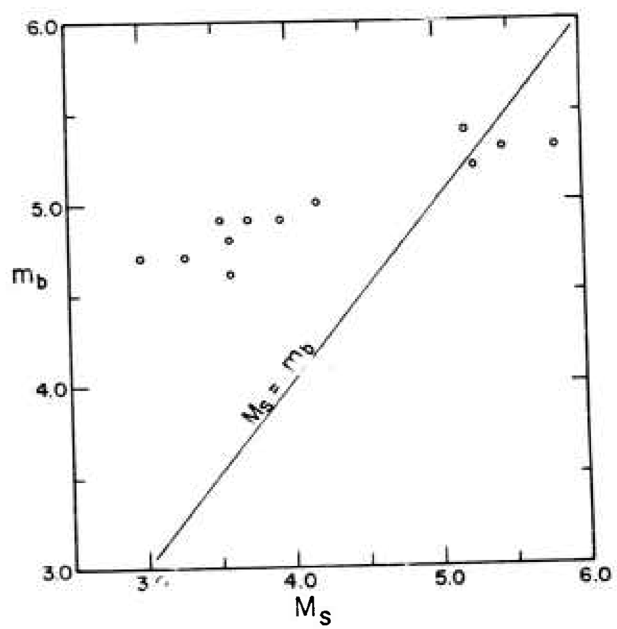

Fig. 3.

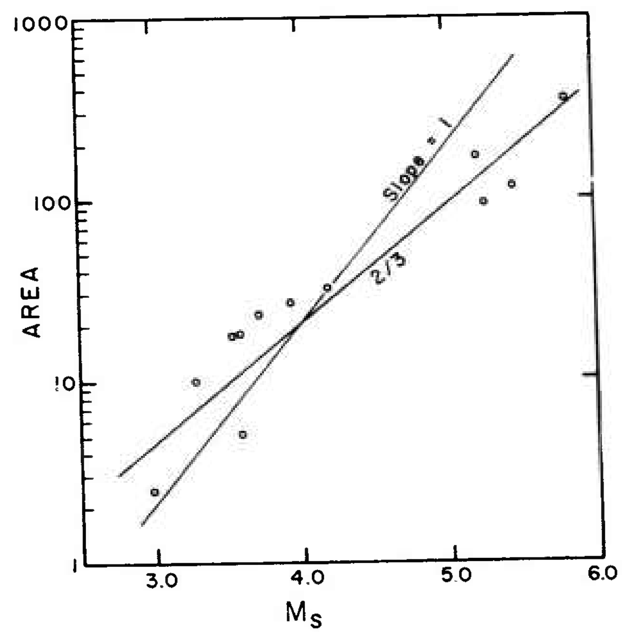

Fig. 4.

From a similar survey of the source regions of seismic sea waves, or tsunamis, Kelleher (1976) indicates that many have important features in common, and that at the present time, there exists a number of sites which appear to fit these occurrence patterns of past tsunamis. Probably a majority of great tsunamis were generated along subducting margins by low-angle, thrust-type earthquakes which had rupture zones extending as much as several hundred kilometers along strike. For these great earthquakes, therefore, large vertical deformations of the sea floor occurred because of the large seismic moments (proportional to fault area × displacement), and despite the typically low angles of faulting (10° to 30°). Crude estimates of the size and location of some future shocks of this important class of earthquakes are possible by the technique of seismic gaps (segments of major plate boundaries that have not ruptured for many years). Thus, significant seismic gaps along subduction boundaries deserve attention as potential locations for future tsunamis.

A major new emphasis in research concerns the development of the inner wall of the trench and its relationship to the size and frequency of great earthquakes. The presence of numerous scarps and large deep-sea terraces within a well-developed pattern of imbricate thrust-faulting may be intimately related to and possibly an indicator of the episodic release of tectonic strain through great earthquakes.

Line - Item 001b

Surface wave data from more than ten Tibetan earthquakes have been digitized and moving window analyzed. The period range is 5 - 100 second with the corresponding group velocity window of 2.3 - 4.1 km/sec/ The observed dispersion curves have been made and compared with their respective theoretical curves.

We have constructed for the Tibetan Plateau, a number of crustal and upper mantle models which we consider represent excellent average structures along the travel paths. One of them, TP-3 model, is shown in the following table:

RAYLEIGH WAVE

MODEL TP-3

Layer No.	Thickness	Dep.	P Velocities	S Velocities	Density
1	3.5000	3.5000	4.5000	2.6000	2.4000
2	34.5000	38.0000	5.9800	3.4500	2.8000
3	30.0000	68.0000	6.3000	3.6400	2.9000
4	INF	INF	8.0000	4.6000	3.4000

The main findings contained in our preliminary report still hold true except that there now appears to be some doubts regarding the existence of a relatively underformed layer of low velocity sediments. Since the existence (or non-existence) of the underformed layer of low velocity sediments

proposed by Chen and Molnar (1975) has important tectonic implications, we have made some preliminary investigation into it. We think that the surface wave dispersion across the Gange (to reach NDI and LAH stations) and the complexities in the Himalayans have such significant effect (especially in the short period range) that care has to be fully exercised when analyzing the high frequency surface waves.

LIST OF PERSONNEL

Scientists:

Lynn R. Sykes | Andrew J. Murphy

Graduate Students:

V. Cormier
S. Nishenko
S. Wesnouski

Problems Encountered:

None

Action Required by the Government:

None

Future Plans:

Future plans call for the continuation of the research outlined above and in other areas specifically related to this project.

Fiscal Status:

Estimated expenses through close of present report period - $26,506.

Total cost to 30 September 1976 - $74,280

List of Publications Supported by this Contract:

Chun, K.Y., and T. Yoshii, Crustal structure of the Tibetan Plateau: A surface wave study by a moving window analysis, Bull. Seism. Soc. Am., submitted, 1976.